

FORM PTO-1390 (Modified)  
(REV 10-95)

## U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

9847-0052-6X PCT

PCT  
E

TRANSMITTAL LETTER TO THE UNITED STATES  
 DESIGNATED/ELECTED OFFICE (DO/EO/US)  
 CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

09/555028

INTERNATIONAL APPLICATION NO.  
PCT/SE98/02166 ✓INTERNATIONAL FILING DATE  
NOVEMBER 27, 1998 ✓PRIORITY DATE CLAIMED  
NOVEMBER 28, 1997 ✓

## TITLE OF INVENTION

A METHOD FOR MANUFACTURING A STATOR FOR A ROTATING ELECTRIC MACHINE, WHERE THE  
 STATOR WINDING INCLUDES JOINTS, A STATOR AND A ROTATING ELECTRIC MACHINE ✓

## APPLICANT(S) FOR DO/EO/US

Lars GERTMAR, et al. ✓

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1.  This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2.  This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3.  This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4.  A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5.  A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a.  is transmitted herewith (required only if not transmitted by the International Bureau).
  - b.  has been transmitted by the International Bureau.
  - c.  is not required, as the application was filed in the United States Receiving Office (RO/US).
6.  A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7.  A copy of the International Search Report (PCT/ISA/210).
8.  Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a.  are transmitted herewith (required only if not transmitted by the International Bureau).
  - b.  have been transmitted by the International Bureau.
  - c.  have not been made; however, the time limit for making such amendments has NOT expired.
  - d.  have not been made and will not be made.
9.  A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10.  An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11.  A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12.  A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

## Items 13 to 18 below concern document(s) or information included:

13.  An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14.  An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15.  A **FIRST** preliminary amendment.  
**A SECOND or SUBSEQUENT** preliminary amendment.
16.  A substitute specification.
17.  A change of power of attorney and/or address letter.
18.  Certificate of Mailing by Express Mail
19.  Other items or information:

## Request for Consideration of Documents Cited in International Search Report

Notice of Priority

Form PTO 1449

List of Related Cases

Marked-up Specification

Response to Petition Under 37 CFR 1.182

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR <b>09/555028</b>	INTERNATIONAL APPLICATION NO. PCT/SE98/02166	ATTORNEY'S DOCKET NUMBER 9847-0052-6X PCT																				
20. The following fees are submitted:		<b>CALCULATIONS PTO USE ONLY</b>																				
<b>BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :</b>																						
<input type="checkbox"/> Search Report has been prepared by the EPO or JPO ..... \$840.00 <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482) ..... \$670.00 <input type="checkbox"/> No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) ..... \$760.00 <input checked="" type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$970.00 <input type="checkbox"/> International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) ..... \$96.00																						
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<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>																						
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492 (e)).		□ 20 <input checked="" type="checkbox"/> 30 <b>\$130.00</b>																				
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>CLAIMS</th> <th>NUMBER FILED</th> <th>NUMBER EXTRA</th> <th>RATE</th> </tr> </thead> <tbody> <tr> <td>Total claims</td> <td>32 - 20 =</td> <td>12</td> <td>x \$18.00    <b>\$216.00</b></td> </tr> <tr> <td>Independent claims</td> <td>4 - 3 =</td> <td>1</td> <td>x \$78.00    <b>\$78.00</b></td> </tr> <tr> <td colspan="2">Multiple Dependent Claims (check if applicable).</td> <td style="text-align: right;"><input type="checkbox"/></td> <td style="text-align: right;"><b>\$0.00</b></td> </tr> <tr> <td colspan="2"></td> <td style="text-align: right;"><b>TOTAL OF ABOVE CALCULATIONS =</b></td> <td style="text-align: right;"><b>\$1,394.00</b></td> </tr> </tbody> </table>		CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	Total claims	32 - 20 =	12	x \$18.00 <b>\$216.00</b>	Independent claims	4 - 3 =	1	x \$78.00 <b>\$78.00</b>	Multiple Dependent Claims (check if applicable).		<input type="checkbox"/>	<b>\$0.00</b>			<b>TOTAL OF ABOVE CALCULATIONS =</b>	<b>\$1,394.00</b>	
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Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) (check if applicable).		<input type="checkbox"/> <b>\$0.00</b>																				
		<b>SUBTOTAL =</b>	<b>\$1,394.00</b>																			
Processing fee of <b>\$130.00</b> for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492 (f)).		□ 20 <input type="checkbox"/> 30    + <b>\$0.00</b>																				
		<b>TOTAL NATIONAL FEE =</b>	<b>\$1,394.00</b>																			
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable).		<input type="checkbox"/> <b>\$0.00</b>																				
		<b>TOTAL FEES ENCLOSED =</b>	<b>\$1,394.00</b>																			
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		<b>charged</b>	\$																			

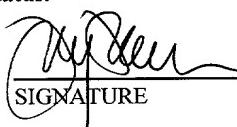
- A check in the amount of **\$1,394.00** to cover the above fees is enclosed.
- Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \_\_\_\_\_ to cover the above fees. A duplicate copy of this sheet is enclosed.
- The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **15-0030** A duplicate copy of this sheet is enclosed.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

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WILLIAM E. BEAUMONT  
REGISTRATION NUMBER 30,996



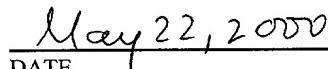
SIGNATURE

Gregory J. Maier

NAME

25,599

REGISTRATION NUMBER



DATE

09/555028

9847-0052-6XPCT  
ENKEL 8340

422 Rec'd PCT/PTO 22 MAY 2000

**IN THE UNITED STATES PATENT & TRADEMARK OFFICE**

IN RE APPLICATION OF :  
  
GERTMAR, L., ET AL. : ATTN: APPLICATION DIVISION  
  
SERIAL NO: NEW APPLICATION :  
(BASED ON PCT SE98/02166)  
  
FILED: HEREWITH :  
  
FOR: A METHOD FOR MANUFACTURING :  
A STATOR FOR A ROTATING ELECTRIC  
MACHINE, WHERE THE STATOR...

**PRELIMINARY AMENDMENT**

ASSISTANT COMMISSIONER OF PATENTS  
WASHINGTON, DC 20231

Prior to examination on the merits, please amend the above-identified application as follows:

**IN THE CLAIMS**

Please cancel Claims 1-31 without prejudice or disclaimer and add Claims 32-63 as follows:

--32. A method of manufacturing a winding of a stator for a rotating electric machine for high voltage, comprising steps of:  
  
receiving the winding in slots of the stator and forming with the winding radial layers at different radial distances from an air gap between the stator and a rotor, including

forming a coil with a part of the winding that runs back and forth once through the stator between different layers, said coil having an arc-shaped coil end projecting from each end surface of the stator,

forming a coil overhang for each of the windings at each of the coil ends, and placing joints between coils in the winding outside the respective coil overhangs.

33. A method according to claim 32, wherein:

said receiving step includes receiving an insulated electric conductor as a material that forms the winding; and

said forming a coil overhang step includes drawing out ends of the insulated electric conductor outside of the coil overhang to where the joints are placed in said placing step.

34. A method according to claim 33, further comprising:  
drawing out an end of the insulated electric conductor a predetermined distance beyond the coil overhang and forming with the end an output terminal for providing a lower voltage than said high voltage

35. A method according to claim 34, further comprising a step of:  
connecting the output terminal to another apparatus.

36. A method according to any of claims 32, wherein:  
said forming a coil step includes threading the insulated electric conductor axially back and forth repeatedly in the slots of the stator.

37. A method according to claim 32, further comprising:  
enclosing a generated electric field within the winding in at least one winding turn.

38. A method according to claim 32, wherein:

said receiving step includes receiving an insulated electric conductor as the winding,  
said insulated electric conductor comprising  
    a current-carrying conductor,  
    a first layer with semiconducting properties arranged around the  
current-carrying conductor,  
    a solid insulating layer arranged around said first layer, and  
    a second layer with semiconducting properties arranged around the insulating  
layer.

39. A method according to claim 38, wherein:

said forming a coil step includes flexing the insulated electric conductor to form the  
coil while having said first layer remain adhered to the solid insulating layer, and said solid  
insulating layer remaining adhered to said second layer.

40. A method according to claim 38, wherein:

said forming a coil step includes forming the coil with a high-voltage cable that  
embodies the insulated electric conductor.

41. A method according to claim 38, wherein:

said forming a coil step includes forming the coil the insulated electric conductor  
having the first layer, solid insulating layer and second layer made with materials exhibiting  
an elasticity and coefficients of thermal expansion such that volume changes of the layers,  
caused by temperature variations during operation, are absorbed by the elasticity of the  
materials such that the layers retain an adhesion to one another when exposed to temperature  
variations which arise during operation.

42. A method according to claim 41, wherein the materials in the first layer, solid insulating layer, and second layer have a high elasticity with an E-modulus less than 500 MPa.

43. A method according to claim 41, wherein the coefficients of thermal expansion of the materials in said first layer, said solid insulating layer, and said second layer being substantially equal to one another.

44. A method according to claim 41, wherein an adhesion between pairs of the first layer and the solid insulating layer, and the solid insulating layer and the second layer being of at least a same order of magnitude as in a weakest of the materials.

45. A method according to any of claims 38, wherein the second layer is configured to constitute a substantially equipotential surface while the current carrying conductor carries a high voltage.

46. A method according to claim 45, further comprising a step of:  
connecting the second semi-conducting layer to ground potential.

47. A method according to claim 38, further comprising a step of:  
holding respective surfaces of each of the first layer and the second layer at different equipotentials.

48. A method according to claim 32, wherein:  
said forming a coil step is performed during a final mounting of the winding in the stator.

49. A method according to claim 32, further comprising a step of:  
supplying a lubricant while drawing said winding through said slots in said stator in said receiving step.

50. A method according to claim 49, further comprising a step of:  
drawing a bracing hose through the stator slots after the winding has been drawn  
through the stator slots in said receiving step.
51. A method according to claim 49, wherein said supplying the lubricant step  
includes supplying a dry lubricant.
52. A method according to claim 32, further comprising a step of:  
attaching the winding to the stator slots with resilient elements.
53. A method according to any of claim 38, wherein:  
an insulation system of the winding comprising  
the first layer, the insulating layer, the second layer each formed by extrusion.
54. A method according to claim 38, said insulating layer having a high  
coefficient of linear expansion.
55. A method according to claim 38, wherein the current-carrying conductor  
includes mutually insulated strands.
56. A method according to any of claims 38, wherein the current-carrying  
conductor has a continuous, uncontrolled transposition.
57. A method according to claim 38, wherein the current-carrying conductor has a  
circular cross section.
58. A method according to claim 38, wherein the current-carrying conductor is  
configured to carry a current of less than 1000 A.
59. A method according to claim 32, wherein the winding includes a continuous  
corona protection device.

60. A method according to claim 59, further comprising a step of grounding the corona protection device.

61. A stator for a high-voltage rotating electric machine comprising:  
a stator core having slots and a central void region;  
a rotor that is positioned in the central void region;  
a winding drawn through said slots in the stator core, wherein  
the winding is positioned in radial layers at different radial distances from an air gap  
between the stator and a rotor,  
a part of the winding that runs back and forth once through the stator between  
different layers arranged as separate coils, each of said coils having an arc-shaped coil end  
projecting from each end surface of the stator, each coil having a coil overhang at each end of  
the coil, and joints between respective of the coils being positioned outside respective coil  
overhangs.

62. A rotating electric machine for high voltage, comprising:  
a stator core having slots and a central void region;  
a rotor that is positioned in the central void region;  
a winding drawn through said slots in the stator core, wherein  
the winding is positioned in radial layers at different radial distances from an air gap  
between the stator and a rotor,  
a part of the winding that runs back and forth once through the stator between  
different layers arranged as separate coils, each of said coils having an arc-shaped coil end  
projecting from each end surface of the stator, each coil having a coil overhang at each end of

the coil, and joints between respective of the coils being positioned outside respective coil overhangs.

63. A stator for a high-voltage rotating electric machine, comprising:

- a stator core having slots and a central void region;
- a rotor that is positioned in the central void region;
- a winding drawn through said slots in the stator core;
- means for receiving the winding in said slots of the stator and means for forming a coil with portions of the winding arranged in radial layers at different radial distances from an air gap between the stator core and the rotor, said means for forming a coil including
  - means for forming the coil having an arc-shaped coil end projecting from each end surface of the stator,
  - means for forming a coil overhang for each of the windings at each of the coil ends, and
  - means for placing joints between coils in the winding outside the respective coil overhangs.--

**IN THE ABSTRACT OF THE DISCLOSURE**

After the last page of the Specification, please insert the following:

--

ABSTRACT OF THE DISCLOSURE

A method for the manufacture of a winding for a stator of a rotating electric machine that operates at high voltage. The stator includes a core provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and the rotor. The part of the winding which runs back and forth once through the stator between various layers forms a coil, with an arc-shaped coil end projecting outside each end surface of the stator. The coil ends from all the windings of the stator form a coil overhang at each end of the stator. The necessary joints in the winding are placed outside the coil overhang--

**REMARKS**

Favorable consideration of this Application as presently amended is respectfully requested.

Claims 32-63 are active in the present Application; Claims 1-31 having been canceled and Claims 32-63 added by way of the present Preliminary Amendment. The new claims have been added to draft the canceled claims in a manner consistent with U.S. practice. It is therefore believed that no issues of new matter have been raised.

Entry of the enclosed substitute specification is respectfully requested. Because several amendments have been made to the specification, consistent with U.S. patent drafting practice, a marked-up copy of the original application is filed herewith. To the extent that any of the changes made by the substitute specification are deemed to be substantively inconsistent with the originally filed specification, these changes should be construed as typographical errors and the language included in the originally-filed PCT application should be construed as containing the controlling language.

The present document is one of a set of patent applications containing related technology as was discussed in "response to petition under 37 C.F.R. §1.182 seeking special treatment relating to an electronic search tool, and decision on petition under 37 C.F.R. §1.183 seeking waiver of requirements under 37 C.F.R. §1.98," filed in the holding application (U.S. Patent Application No. 09/147,325). Consistent with this decision, a copy of the decision is filed herewith. Also, an Information Disclosure Statement is filed herewith including a PTO Form 1449 with references that are included as part of the specially-created official digest in class 174. It is believed that submission of these materials and the reference to the holding application (Serial No. 09/147,325) is sufficient for the

present Examiner to consider the references in the holding application, consistent with the decision.

Accordingly, examination on the merits of Claims 32-63 is believed to be in order, and an early and favorable action is respectfully requested.

Respectfully submitted,

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WILLIAM E. BEAUMONT  
REGISTRATION NUMBER 30,996

SUBSTITUTE SPECIFICATION

9847-0052-6XPCT  
ENKEL 8340

5

TITLE OF THE INVENTION

A METHOD FOR MANUFACTURING A STATOR FOR A ROTATING ELECTRIC  
MACHINE, A STATOR AND A ROTATING ELECTRIC MACHINE

10

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to a method for manufacturing the winding of a stator for a rotating electric machine for high voltage. The invention also relates to a stator manufactured by this method, and a rotating electric machine that includes a stator manufactured by this method.

Discussion of the Background:

The rotating electric machines which are referred to in this context include synchronous machines, which are principally used as generators for connection to distribution and transmission networks, commonly called power networks. The synchronous machines are also used as motors as well as for phase compensation and voltage control, and, in that case, as mechanically open-circuited machines. This technical field also includes normal asynchronous machines, double-fed machines, AC machines, asynchronous converter cascades, external pole machines, and synchronous flux machines. These machines are intended to be used at high voltages, by which are meant here electric voltages which primarily exceed 10 kV. A typical range of operation for such a rotating machine may be 36 - 800 kV, and preferably 72.5 - 800 kV.

Rotating electric machines have conventionally been designed for voltages within the interval 6 - 30 kV, and 30 kV has normally been considered to be an upper limit. In the generator case, this normally implies that a generator must be connected to the power network via a transformer which steps up the voltage to the level of the network, which lies within the range of about 130 - 400 kV.

Over the years, various attempts have been made to develop special synchronous machines, preferably generators, for higher voltages. Examples of this are described, inter-

alia, in "Electrical World", October 15, 1932, pages 524-525, the article "Water-and-Oil-cooled Turbogenerator TVM-300" in J. Elektrotechnika, No. 1, 1970, pages 6-8, and patent publications US 4,424,244 and SU 955 369. However, none of these attempts have been successful, nor have they resulted in any commercially available product.

5        In conventional types of rotating electric machines, the stator body often includes a welded sheet-steel structure. In large machines, the stator core, also called the laminated core, is normally made of preferably 0.35-0.50 mm thick so-called electric sheets divided into stacks. The stator core is provided with radial slots for receiving the winding in radial layers at different radial distances from the air gap which is provided between the stator  
10      and a rotor. The word layer thus indicates layers of the winding at different radial distances from the centre axis of the stator. That part of the winding which runs back and forth once through the stator between different layers forms one winding turn, and several winding turns are normally collected into a so-called coil. A coil thus has several aggregated conductors, insulated from each other, with an arc-shaped coil end outside each end surface of  
15      the stator. The coil ends from all the windings of the stator form a coil overhang at each end of the stator.

20       Normally, all large, conventionally constructed generators are provided with a two-layer winding and equally large coils. The fact that the coils must be equally large is due to the generators for high powers often requiring a parallel connection of the coils. The coils are stiff and prefabricated and the winding is installed by inserting coils in a radial direction into the slots of the stator core. Joining or connection then takes place between each coil in the winding when all the coils have been placed in position in their slots. Because all the coils must have the same size, all the joints must be placed in the coil overhang. The coil overhang will therefore contain a large number of joints. This method has the disadvantage of being time-consuming and results in a number of joints which are sensitive to various kinds of faults and external influence.  
25

#### SUMMARY OF THE INVENTION

The object of the present invention is to solve the above-mentioned problems. This object is achieved by way of a method for manufacturing a winding of a stator for a  
30      rotating electric machine for high voltage. The stator of this method has a core provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which

runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end projecting from each end surface of the stator, the coil ends from all the windings of the stator forming a coil overhang at each end of the stator, which has the characteristic feature that the necessary joints between coils in the winding are placed outside the coil overhang .

Thus, the present invention relates to a method for the manufacture of a winding for a stator of a rotating electric machine for high voltage, wherein the stator includes a core provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and the rotor, whereby that part of the winding which runs back and forth once through the stator between various layers forms a coil, with an arc-shaped coil end projecting outside each end surface of the stator, the coil ends from all the windings of the stator forming a coil overhang at each end of the stator, the method being characterized in that the necessary joints in the winding are placed outside the coil overhang.

The method described has the essential advantage that the winding may be jointed or spliced in a very simple manner. Instead of jointing each coil inside the coil overhang, which is narrow and awkward, the winding may thus be jointed outside the coil overhang where there is ample space and easy access. One advantage of the winding of the kind discussed above is that it allows series connection of the coils. In case of a series connection, it is not required that the coils be equally large, and, therefore, a freer location of the necessary joints is possible, which makes the present invention possible.

Another advantage achieved with the method is that it will be possible to provide output terminals for lower voltages in the winding at optional locations, which locations are situated outside the coil end overhang.

Additional advantages and characteristic features will become clear from [the dependent claims] the discussion below.

According to a particularly advantageous feature, the method is characterized in that the winding includes an insulated electric conductor and that ends of insulated electric conductors in the winding are drawn out outside the coil overhang, where the respective ends are joined to ends of other insulated electric conductors in the winding.

According to another advantageous characteristic feature, it is stated that the end of at least one of the insulated electric conductors of the winding is drawn out to an op-

tional extent outside the coil end region, where it forms an output terminal for lower voltage, for example an external power network. The output terminals may be varied as desired as regards location, voltage, number, etc. In principle, such a long conductor may be drawn out that it may be extended to the nearest switchgear, without the need of supporting bars and the like. As an additional advantageous characteristic feature, it is thus stated that the end of at least one of the insulated electric conductors of the winding is drawn out to an optional extent outside the coil overhang, where it is connected to an optional apparatus. Such an apparatus may be a generator breaker and/or a disconnector or the above-mentioned switchgear and, in that case, it is thus a question of full voltage.

10 Furthermore, the method according to the invention is characterized in that the winding is achieved by threading the insulated electric conductor axially back and forth repeatedly in the slots in the stator core. In this way, many coils, i.e. turns in the winding, may be achieved without interruption and without joints, which is both time-saving and cost-effective. Further, it has the advantage that the winding is not formed until the final 15 mounting in the stator core and no preforming is therefore required.

According to a particularly advantageous characteristic feature, the insulated electric conductor is provided with a mechanism configured to enclose a generated electrical field inside the winding for at least one winding turn.

According to the invention, the windings are preferably of a type corresponding to 20 cables having solid, extruded insulation, of a type now used for power distribution, such as XLPE-cables or cables with EPR-insulation. Such a cable includes an inner conductor composed of one or more strand parts, an inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding this and an outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an important property in 25 this context since the technology for the arrangement according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of an XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve 30 times the cable diameter.

The winding should be constructed to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this context. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE-cable, for instance, the insulating layer is formed from cross-linked, low-density polyethylene, and the semiconducting layers may be formed from polyethylene with soot and metal particles mixed in. Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having a resistivity within the range of  $10^{-1}$ - $10^6$  ohm·cm, e.g. 15 1-500 ohm·cm, or 10-200 ohm·cm, naturally also fall within the scope of the invention.

The insulating layer may be formed, for example, from a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene ("TPX"), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR), or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficient of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber (EVA/NBR), butyl graft polyethylene, ethylene-butyl-acrylate copolymers (EBA), and ethylene-ethyl-acrylate copolymers (EEA) may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of 5  $E < 500$  MPa, preferably  $< 200$  MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction by the elasticity so that no cracks, or any other damage appear, and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as in the weakest of the 10 materials.

The conductivity of the two semiconducting layers is sufficient to substantially 15 equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently high to enclose the electrical field within the cable, but sufficiently low not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

By using an insulated conductor as described above as a winding in a rotating 20 electric machine, the important advantage is achieved that the voltage of the machine may be increased to such levels that it may be directly connected to the power network without intermediate transformers. Thus, for example, the very important advantage is achieved that the conventional transformer may be eliminated.

To continue, the winding is further characterized in that it is made with an insulated 25 electric conductor including at least one current-carrying conductor, and that the field-enclosing members mentioned includes a first layer with semiconducting properties arranged to surround the current-carrying conductor, a solid insulating layer arranged to surround the first-mentioned layer, and a second layer with semiconducting properties arranged to surround the insulating layer.

According to a particularly advantageous characteristic feature, the insulated electric conductor is flexible and the three layers adhere to one another, which, among

other things, has the advantage of facilitating installation and removal of the winding, respectively.

The high-voltage insulated electric conductor may be designed in a plurality of advantageous ways. As one advantageous feature it is stated that the insulated conductor is formed from a cable, preferably a high-voltage cable. Further, the first semiconducting layer is substantially at the same potential as the current-carrying conductor. The second semiconducting layer is preferably arranged so as to constitute a substantially equipotential surface surrounding the current-carrying conductor/conductors and the insulating layer. It is also connected to a predetermined potential, preferably ground potential. According to another characteristic feature, the current-carrying conductor may have a number of strands, whereby only a few of the strands are uninsulated from one another.

Finally, it may be mentioned that the insulated conductor preferably has a diameter which is in the interval 20-250 mm and a conductor area which is in the interval 80-300 mm<sup>2</sup>.

The insulated conductor or high-voltage cable which is used in the present invention is, as mentioned, flexible and of the kind described in more detail in PCT applications SE97/00874 (WO 97/45919) and SE97/00875 (WO 97/45847). A further description of the insulated conductor or cable is to be found in PCT-applications SE97/00901 (WO 97/45918), SE97/00902 (WO 97/45930), and SE97/00903 (WO 97/45931).

According to a particularly advantageous feature, the winding is characterized in that it is formed during the final mounting in the core. As already mentioned, this facilitates the manufacture since no preforming is necessary.

The method is also characterized in that a lubricant is supplied when the winding is drawn through the stator slots. Where applicable, a bracing hose for the winding may be drawn through the stator slots, after the winding has been drawn, and the method is then characterized in that a lubricant is supplied to the slots in connection with the bracing hose being drawn. This lubricant is preferably a dry lubricant. An example of a suitable lubricant is boron nitride, preferably of a lamellar structure. Examples of so-called bracing hoses are described in the patent applications SE 9700362-8, SE 9700363-6, PCT/SE97/00897 (WO 97/45935), PCT/SE97/00898 (WO 97/45936), PCT/SE97/00906 (WO 97/45938), and PCT/SE97/00907 (WO 97/45932).

Finally, the method is characterized in that the winding is attached in the stator slots by way of resilient elements, for example a bracing hose of some of the kinds described in the above-mentioned patent applications.

Further, the insulation system of the winding having the first and second semi-conducting layers, respectively, and the insulating layer positioned therebetween, may be manufactured by extrusion. The insulation of the winding is preferably manufactured of a material with a high coefficient of linear expansion.

According to one characteristic feature, the winding has mutually insulated strands in the current-carrying conductor. Further, it is stated that the current-carrying conductor of the winding has a continuous, uncontrolled transposition. This simplifies the manufacture of the winding. The current-carrying conductor also advantageously has a circular cross section, which also has the advantage of simplifying the manufacture in that the conductor may be bent in an arbitrary direction.

As a further characteristic feature it is stated that the current in the current-carrying conductor of the winding is low, preferably less than 1000 A. This has the advantage of resulting in lower mechanical forces because of fault currents, compared with conventional machines. It also implies that the bracing of the coil end is simplified.

Further, the method is characterized in that the winding has a continuous corona protection device, which is advantageously grounded. The corona protection device contains the second semi-conducting layer.

The present invention also relates to a stator for a rotating electric machine for high voltage, having a stator core and a winding, which is characterized in that the winding is manufactured in accordance with the method [according to any of the claims relating to the method] herein described. The invention also relates to a rotating electric machine for high voltage having the described stator.

In summary, thus, the present invention provides a considerably simplified method for the manufacture of a winding, which shows the way to other improvements and also directly results in technical advantages as well as advantages from the point of view of cost.

## BRIEF DESCRIPTION OF THE DRAWINGS

To increase the understanding of the invention, it will now be described in detail, with reference to the accompanying drawings, illustrating a non-limiting embodiment, wherein

- 5      Figure 1    schematically shows, in perspective, a part view of a stator end with coil ends containing unjointed conductors,
- Figure 2    schematically shows, in perspective view, the stator end in Figure 1, after jointing, and
- Figure 3    shows an insulated electric conductor, in cross section, which is suitable for use  
10                  as a winding.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 schematically illustrates an example of a part of a coil overhang 1 of an end surface 3 of a stator core 2 according to the present invention. The figure shows that the winding is arranged in radial layers at different radial distances from the air gap present  
15                  between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end 5 projecting from each end surface 3 of the stator, the coil ends from all the windings of the stator forming a coil overhang 1 at each end of the stator.

The winding in the figure is achieved by threading a cable or an insulated electric  
20                  conductor (6) of the kind described above axially back and forth repeatedly in the slots in the stator core 2, whereby a plurality of coils are being formed without joints. However, the length of the cable (6) is not infinite, but sooner or later the first cable comes to an end and a new cable must be used. As a result of this, the coil overhang 1 will exhibit a number of loosely hanging cable ends 8, 9, 15, which, for example, are to be joined with each  
25                  other. These cable ends are located outside the actual coil overhang 1.

Figure 2 shows the same stator end as in Figure 1 but with the difference that the loose cable ends 8, 9 have here been joined with each other by way of some suitable type of cable joint 12, preferably a prefabricated cable joint. As is clear, the joints are also outside the coil overhang 1. The joints may possibly be attached mechanically to some type of support, which, however, is not shown in the figure.  
30

In the example shown, the jointing has been performed only after at least a major part of the winding has been placed in position, but it is, of course, possible to join the ca-

ble ends as the winding is being threaded. Usually, however, the entire winding is threaded before jointing takes place.

Figure 2 also shows an example of a winding end 15 which serves as a partial output terminal 16 for voltage or, alternatively, is optionally connected, for example to a switchgear unit or a generator breaker.

Finally, Figure 3 shows a cross section of a cable which is particularly suited for use as a winding in the stator according to the invention. The cable 30 includes at least one current-carrying conductor 31 surrounded by a first semiconducting layer 32. Around this first semiconducting layer, there is arranged an insulating layer 33, and around this layer there is arranged, in its turn, a second semiconducting layer 34. The electric conductor 31 may include a number of strands 35. The three layers are formed such that they adhere to one another also when the cable is bent. The shown cable is flexible and this property is retained in the cable during its service life. The illustrated cable also differs from a conventional high-voltage cable in that the outer mechanically protecting casing and the metal screen which normally surrounds a conventional cable may be eliminated.

The invention should not be considered limited to the illustrated embodiment, but may, of course, include a number of variations and modifications within the scope of the inventive concept, as it is defined in the subsequent claims. For example, the number of joints and/or output terminals may be varied where necessary and desired. Further, the winding may, for example, also be installed radially.

CLAIMS

1. A method for manufacturing a winding of a stator for a rotating electric machine for high voltage, the stator comprising a core (2) provided with slots for receiving the  
5 winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end (5) projecting from each end surface (3) of the stator, the coil ends from all the windings of the stator forming a coil overhang (1) at each end (3) of the stator, **characterized** in that  
10 the necessary joints (12) between coils in the winding are placed outside the coil overhang.
2. A method according to claim 1, **characterized** in that the winding comprises an insulated electric conductor (6) and that ends (8, 9, 15) of the insulated electric conductor (6) in the winding are drawn out outside the coil overhang (1) where the respective ends  
15 are joined to ends of other insulated electric conductors (6) in the winding, located there.
3. A method according to claim 1 or 2, **characterized** in that the end (15) of at least one of the insulated electric conductors (6) of the winding is drawn out an optional distance outside the coil overhang, where it forms an output terminal (16) for lower voltage.  
20
4. A method according to any of claims 1-3, **characterized** in that the end (15) of at least one of the insulated electric conductors (6) of the winding is drawn out an optional distance outside the coil overhang, where it is connected to an optional apparatus.
- 25 5. A method according to any of claims 2-4, **characterized** in that the winding is achieved by threading the insulated electric conductor (6) axially back and forth repeatedly in the slots of the stator core (2).
- 30 6. A method according to any of the preceding claims, **characterized** in that the insulated electric conductor (6) in the winding is provided with means for enclosing a generated electric field within the winding during at least one winding turn.

7. A method according to any of the preceding claims, **characterized** in that the winding is provided by means of an insulated electric conductor (30) comprising at least one current-carrying conductor (31), and that said field-enclosing means comprise a first layer (32) with semiconducting properties arranged surrounding the current-carrying conductor, a solid insulating layer (33) arranged surrounding said first layer, and a second layer (34) with semiconducting properties arranged surrounding the insulating layer.

8. A method according to claim 7, **characterized** in that the insulated electric conductor (30) is flexible and that said layers adhere to one another.

10

9. A method according to claim 7 or 8, **characterized** in that the insulated conductor (30) is in the form of a cable, preferably a high-voltage cable.

10. A method according to any of claims 7-9, **characterized** in that said layers (32, 15 33, 34) are of materials with such elasticity and such a relation between the coefficients of thermal expansion of the materials that the volume changes of the layers, caused by temperature variations during operation, are capable of being absorbed by the elasticity of the materials such that the layers retain their adhesion to one another at the temperature variations which arise during operation.

20

11. A method according to claim 10, **characterized** in that the materials in said layers (32, 33, 34) have a high elasticity, preferably with an E-modulus less than 500 MPa, preferably less than 200 MPa.

25

12. A method according to claim 10, **characterized** in that the coefficients of thermal expansion of the materials in said layers are substantially equal.

13. A method according to claim 10, **characterized** in that the adhesion between the layers (32, 33, 34) is of at least the same order of magnitude as in the weakest of the materials.

30

14. A method according to any of claims 7-13, **characterized** in that the second semiconducting layer (34) is arranged so as to constitute a substantially equipotential surface surrounding the current-carrying conductor/conductors (31).

5 15. A method according to claim 14, **characterized** in that the second semiconducting layer (34) is connected to ground potential.

16. A method according to any of claims 7-10, **characterized** in that each of the semiconducting layers (32, 34) constitutes essentially an equipotential surface.

10

17. A method according to any of the preceding claims, **characterized** in that the winding is formed during the final mounting in the core.

15

18. A method according to any of the preceding claims, **characterized** in that a lubricant is supplied when the winding is drawn through the stator slots.

19. A method according to any of the preceding claims, **characterized** in that a bracing hose is drawn through the stator slots, after the winding has been drawn, whereby a lubricant is supplied to the slots.

20

20. A method according to any of claims 18-19, **characterized** in that the lubricant is a dry lubricant.

25

21. A method according to any of the preceding claims, **characterized** in that the winding is attached to the stator slots by means of resilient elements.

22. A method according to any of claims 7-21, **characterized** in that the insulation system of the winding comprising the first (32) and second (34) semiconducting layers, respectively, and the insulating layer (33) located therebetween, is manufactured by extrusion.

30

23. A method according to any of claims 7-22, **characterized** in that the insulation of the winding is manufactured of a material with a high coefficient of linear expansion.

24. A method according to any of claims 7-23, **characterized** in that the winding has mutually insulated strands in the current-carrying conductor (31).

25. A method according to any of claims 7-24, **characterized** in that the current-carrying conductor (31) of the winding has a continuous, uncontrolled transposition.

10 26. A method according to any of claims 7-25, **characterized** in that the current-carrying conductor (31) of the winding has a circular cross section.

27. A method according to any of claims 7-26, **characterized** in that the current in the current-carrying conductor (31) of the winding is low, preferably less than 1000 A.

15 28. A method according to any of the preceding claims, **characterized** in that the winding has a continuous corona protection device.

20 29. A method according to claim 28, **characterized** in that the corona protection device is grounded.

30. A stator for a rotating electric machine for high voltage, comprising a stator core and a winding, **characterized** in that the winding is manufactured in accordance with the method according to any of claims 1-29.

25 31. A rotating electric machine for high voltage, comprising a stator in accordance with claim 30.

## ABSTRACT

The invention relates to a method for manufacturing a winding of a stator for a rotating electric machine for high voltage, the stator comprising a core (2) provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which extends back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end (5) projecting from each end surface (3) of the stator, the coil ends from all the windings of the stator forming a coil overhang (1) at each end (3) of the stator.

5 The method is characterized in that the necessary joints (12) between coils in the winding are placed outside the coil overhang (1). The invention also relates to a stator with a winding manufactured according to the method and to a rotating electric machine comprising said stator.

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TITLE OF THE INVENTION

- 5 A METHOD FOR MANUFACTURING A STATOR FOR A ROTATING ELECTRIC  
MACHINE, A STATOR AND A ROTATING ELECTRIC MACHINE

BACKGROUND OF THE INVENTION

Field of the Invention:

10 The present invention relates to a method for manufacturing the winding of a stator for a rotating electric machine for high voltage in accordance with the preamble to claim 1. The invention also relates to a stator ~~in accordance with the preamble to claim 30~~<sup>manufactured by this method</sup>, and a rotating electric machine ~~in accordance with the preamble to claim 31~~<sup>that includes a stator manufactured by this method</sup>.

15

Discussion of the Background:

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The rotating electric machines which are referred to in this context ~~comprise~~<sup>include</sup> synchronous machines, which are principally used as generators for connection to distribution and transmission networks, commonly called power networks. The synchronous machines are also used as motors as well as for phase compensation and voltage control, and, in that case, as mechanically open-circuited machines. This technical field also ~~comprises~~<sup>includes</sup> normal asynchronous machines, double-fed machines, AC<sub>a</sub>e machines, asynchronous converter cascades, external pole machines, and synchronous flux machines. These machines are intended to be used at high voltages, by which are meant here electric voltages which primarily exceed 10 kV. A typical range of operation for such a rotating machine may be 36 - 800 kV, and preferably 72.5 - 800 kV.

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Rotating electric machines have conventionally been designed for voltages within the interval 6 - 30 kV, and 30 kV has normally been considered to be an upper limit. In the generator case, this normally implies that a generator must be connected to the power network via a transformer which steps up the voltage to the level of the network, which lies within the range of about 130 - 400 kV.

Over the years, various attempts have been made to develop special synchronous machines, preferably generators, for higher voltages. Examples of this are described, inter alia, in "Electrical World", October 15, 1932, pages 524-525, the article "Water-and-Oil-

cooled Turbogenerator TVM-300" in J. Elektrotehnika, No. 1, 1970, pages 6-8, and patent publications US 4,424,244 and SU 955 369. However, none of these attempts haves been successful, nor have they resulted in any commercially available product.

In conventional types of rotating electric machines, the stator body often ~~com-~~  
5 ~~prises~~includes a welded sheet-steel structure. In large machines, the stator core, also called the laminated core, is normally made of preferably 0.35-0.50 mm thick so-called electric sheets divided into stacks. The stator core is provided with radial slots for receiving the winding in radial layers at different radial distances from the air gap which is provided between the stator and a rotor. The word layer thus ~~means~~indicates layers of the winding at  
10 different radial distances from the centre axis of the stator. That part of the winding which runs back and forth once through the stator between different layers forms one winding turn, and several winding turns are normally collected into a so-called coil. A coil thus ~~comprises~~has several aggregated conductors, insulated from each other, with an arc-shaped coil end outside each end surface of the stator. The coil ends from all the windings  
15 of the stator form a coil overhang at each end of the stator.

Normally, all large, conventionally constructed generators are provided with a two-layer winding and equally large coils. The fact that the coils must be equally large is due to the generators for high powers often requiring a parallel connection of the coils. The coils are stiff and prefabricated and the winding is installed by inserting coils in a radial direction into the slots of the stator core. Joining or connection then takes place between each coil in the winding when all the coils have been placed in position in their slots. Because all the coils must have the same size, all the joints must be placed in the coil overhang. The coil overhang will therefore contain a large number of joints. This method has the disadvantage of being time-consuming and results in a number of joints which are sensitive to  
20 various kinds of faults and external influence.  
25

#### SUMMARY OF THE INVENTION

The object of the present invention is to solve the above-mentioned problems. This object is achieved by ~~means~~way of ~~at~~the method according to the preamble to claim 1, for manufacturing a winding of a stator for a rotating electric machine for high voltage.  
30 The stator of this method has a core provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end projecting from each end surface of the stator, the coil ends from all the windings of the stator forming a coil over-

hang at each end of the stator, which has the characteristic features that the necessary joints between coils in the winding are placed outside the coil overhang described in the characterizing portion.

Thus, the present invention relates to a method for the manufacture of a winding for a stator of a rotating electric machine for high voltage, wherein the stator ~~comprises-includes~~ a core provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and the rotor, whereby that part of the winding which runs back and forth once through the stator between various layers forms a coil, with an arc-shaped coil end projecting outside each end surface of the stator, the coil ends from all the windings of the stator forming a coil overhang at each end of the stator, the method being characterized in that the necessary joints in the winding are placed outside the coil overhang.

The method described has the essential advantage that the winding may be jointed or spliced in a very simple manner. Instead of jointing each coil inside the coil overhang, which is narrow and awkward, the winding may thus be jointed outside the coil overhang where there is ample space and easy access. One advantage of the winding of the kind discussed above is that it allows series connection of the coils. In case of a series connection, it is not required that the coils be equally large, and, therefore, a freer location of the necessary joints is possible, which makes the present invention possible.

Another advantage achieved with the method is that it will be possible to provide output terminals for lower voltages in the winding at optional locations, which locations are situated outside the coil end overhang.

Additional advantages and characteristic features will become clear from [the dependent claims] the discussion below.

According to a particularly advantageous feature, the method is characterized in that the winding ~~comprises-includes~~ an insulated electric conductor and that ends of insulated electric conductors in the winding are drawn out outside the coil overhang, where the respective ends are joined to ends of other insulated electric conductors in the winding.

According to another advantageous characteristic feature, it is stated that the end of at least one of the insulated electric conductors of the winding is drawn out to an optional extent outside the coil end region, where it forms an output terminal for lower voltage, for example an external power network. The output terminals may be varied as desired as regards location, voltage, number, etc. In principle, such a long conductor may be drawn out that it may be extended to the nearest switchgear, without the need of supporting bars

and the like. As an additional advantageous characteristic feature, it is thus stated that the end of at least one of the insulated electric conductors of the winding is drawn out to an optional extent outside the coil overhang, where it is connected to an optional apparatus. Such an apparatus may be a generator breaker and/or a disconnector or the above-  
5 mentioned switchgear and, in that case, it is thus a question of full voltage.

Furthermore, the method according to the invention is characterized in that the winding is achieved by threading the insulated electric conductor axially back and forth repeatedly in the slots in the stator core. In this way, many coils, i.e. turns in the winding, may be achieved without interruption and without joints, which is both time-saving and  
10 cost-effective. Further, it has the advantage that the winding is not formed until the final mounting in the stator core and no preforming is therefore required.

According to a particularly advantageous characteristic feature, the insulated electric conductor is provided with means for enclosing a mechanism configured to enclose a generated electrical field inside the winding for at least one winding turn.

15 According to the invention, the windings are preferably of a type corresponding to cables having solid, extruded insulation, of a type now used for power distribution, such as XLPE-cables or cables with EPR-insulation. Such a cable ~~comprises~~includes an inner conductor composed of one or more strand parts, an inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding this and an outer semiconducting  
20 layer surrounding the insulating layer. Such cables are flexible, which is an important property in this context since the technology for the arrangement according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of an XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a  
25 radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

The winding should be constructed to retain its properties even when it is bent and  
30 when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this context. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE-cable, for instance, the insulating layer ~~consists~~is formed from cross-linked, low-density polyethylene, and the semiconducting layers ~~consist~~may be formed

from polyethylene with soot and metal particles mixed in. Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having a resistivity within the range of  $10^{-1}$ - $10^6$  ohm·cm, e.g. 1-500 ohm cm, or 10-200 ohm·cm, naturally also fall within the scope of the invention.

The insulating layer may consist be formed, for example, from of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene ("TPX"), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR), or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber (EVA/NBR), butyl graft polyethylene, ethylene-butyl-acrylate copolymers (EBA), and ethylene-ethyl-acrylate copolymers (EEA) may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of  $E < 500$  MPa, preferably  $< 200$  MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction by of the elasticity so that no cracks appear, or any other damage appear, and so that the layers are not released from each other. The material in the layers is

elastic, and the adhesion between the layers is at least of the same magnitude as in the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently high to enclose the electrical field within the cable, but sufficiently low not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

By using an insulated conductor as described above as a winding in a rotating electric machine, the important advantage is achieved that the voltage of the machine may be increased to such levels that it may be directly connected to the power network without intermediate transformers. Thus, for example, the very important advantage is achieved that the conventional transformer may be eliminated.

To continue, the winding is further characterized in that it is made with an insulated electric conductor ~~comprising~~ including at least one current-carrying conductor, and that the field-enclosing members mentioned ~~comprise~~ includes a first layer with semiconducting properties arranged to surround the current-carrying conductor, a solid insulating layer arranged to surround the first-mentioned layer, and a second layer with semiconducting properties arranged to surround the insulating layer.

According to a particularly advantageous characteristic feature, the insulated electric conductor is flexible and the three layers adhere to one another, which, among other things, has the advantage of facilitating installation and removal of the winding, respectively.

The high-voltage insulated electric conductor may be designed in a plurality of advantageous ways. As one advantageous feature it is stated that the insulated conductor ~~comprises~~ is formed from a cable, preferably a high-voltage cable. Further, the first semiconducting layer is substantially at the same potential as the current-carrying conductor. The second semiconducting layer is preferably arranged so as to constitute a substantially equipotential surface surrounding the current-carrying conductor/conductors and the insulating layer. It is also connected to a predetermined potential, preferably ground potential. According to another characteristic feature, the current-carrying conductor may ~~comprise~~

have a number of strands, whereby only a few of the strands are uninsulated from one another.

Finally, it may be mentioned that the insulated conductor preferably has a diameter which is in the interval 20-250 mm and a conductor area which is in the interval 80-300  
5 mm<sup>2</sup>.

The insulated conductor or high-voltage cable which is used in the present invention is, as mentioned, flexible and of the kind described in more detail in PCT applications SE97/00874 (WO 97/45919) and SE97/00875 (WO 97/45847). A further description of the insulated conductor or cable is to be found in PCT-applications SE97/00901 (WO  
10 97/45918), SE97/00902 (WO 97/45930), and SE97/00903 (WO 97/45931).

According to a particularly advantageous feature, the winding is characterized in that it is formed during the final mounting in the core. As already mentioned, this facilitates the manufacture since no preforming is necessary.

The method is also characterized in that a lubricant is supplied when the winding is drawn through the stator slots. Where applicable, a bracing hose for the winding may be drawn through the stator slots, after the winding has been drawn, and the method is then characterized in that a lubricant is supplied to the slots in connection with the bracing hose being drawn. This lubricant is preferably a dry lubricant. An example of a suitable lubricant is boron nitride, preferably of a lamellar structure. Examples of so-called bracing hoses are described in the patent applications SE 9700362-8, SE 9700363-6,  
15 PCT/SE97/00897 (WO 97/45935), PCT/SE97/00898 (WO 97/45936), PCT/SE97/00906 (WO 97/45938), and PCT/SE97/00907 (WO 97/45932).

Finally, the method is characterized in that the winding is attached in the stator slots by means-way of resilient elements, for example a bracing hose of some of the kinds described in the above-mentioned patent applications.  
25

Further, the insulation system of the winding comprising having the first and second semiconducting layers, respectively, and the insulating layer positioned therebetween, may be manufactured by extrusion. The insulation of the winding is preferably manufactured of a material with a high coefficient of linear expansion.

According to one characteristic feature, the winding has mutually insulated strands in the current-carrying conductor. Further, it is stated that the current-carrying conductor of the winding has a continuous, uncontrolled transposition. This simplifies the manufacture of the winding. The current-carrying conductor also advantageously has a cir-

cular cross section, which also has the advantage of simplifying the manufacture in that the conductor may be bent in an arbitrary direction.

As a further characteristic feature it is stated that the current in the current-carrying conductor of the winding is low, preferably less than 1000 A. This has the advantage of resulting in lower mechanical forces because of fault currents, compared with conventional machines. It also implies that the bracing of the coil end is simplified.

Further, the method is characterized in that the winding has a continuous corona protection device, which is advantageously grounded. The corona protection device comprises contains the second semi-conducting layer.

The present invention also relates to a stator for a rotating electric machine for high voltage, comprising having a stator core and a winding, which is characterized in that the winding is manufactured in accordance with the method [according to any of the claims relating to the method] herein described. The invention also relates to a rotating electric machine for high voltage comprising having the described stator mentioned.

In summary, thus, the present invention provides a considerably simplified method for the manufacture of a winding, which shows the way to other improvements and also directly results in technical advantages as well as advantages from the point of view of cost.

#### BRIEF DESCRIPTION OF THE DRAWINGS

To increase the understanding of the invention, it will now be described in detail, with reference to the accompanying drawings, illustrating a non-limiting embodiment, wherein

Figure 1 schematically shows, in perspective, a part view of a stator end with coil ends comprising containing unjointed conductors,

Figure 2 schematically shows, in perspective view, the stator end in Figure 1, after jointing, and

Figure 3 shows an insulated electric conductor, in cross section, which is suitable for use as a winding.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 schematically illustrates an example of a part of a coil overhang 1 of an end surface 3 of a stator core 2 according to the present invention. The figure shows that the winding is arranged in radial layers at different radial distances from the air gap present between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end 5

projecting from each end surface 3 of the stator, the coil ends from all the windings of the stator forming a coil overhang 1 at each end of the stator.

The winding in the figure is achieved by threading a cable or an insulated electric conductor (6) of the kind described above axially back and forth repeatedly in the slots in the stator core 2, whereby a plurality of coils are being formed without joints. However, the length of the cable (6) is not infinite, but sooner or later the first cable comes to an end and a new cable must be used. As a result of this, the coil overhang 1 will exhibit a number of loosely hanging cable ends 8, 9, 15, which, for example, are to be joined with each other. These cable ends are located outside the actual coil overhang 1.

Figure 2 shows the same stator end as in Figure 1 but with the difference that the loose cable ends 8, 9 have here been joined with each other by ~~means~~way of some suitable type of cable joint 12, preferably a prefabricated cable joint. As is clear, ~~also~~ the joints are also outside the coil overhang 1. The joints may possibly be attached mechanically to some type of support, which, however, is not shown in the figure.

In the example shown, the jointing has been performed only after at least a major part of the winding has been placed in position, but it is, of course, possible to join the cable ends as the winding is being threaded. Usually, however, the entire winding is threaded before jointing takes place.

Figure 2 also shows an example of a winding end 15 which serves as a partial output terminal 16 for voltage or, alternatively, is optionally connected, for example to a switchgear unit or a generator breaker.

Finally, Figure 3 shows a cross section of a cable which is particularly suited for use as a winding in the stator according to the invention. The cable 30 ~~comprises~~includes at least one current-carrying conductor 31 surrounded by a first semiconducting layer 32. Around this first semiconducting layer, there is arranged an insulating layer 33, and around this layer there is arranged, in its turn, a second semiconducting layer 34. The electric conductor 31 may ~~comprise~~include a number of strands 35. The three layers are formed such that they adhere to one another also when the cable is bent. The shown cable is flexible and this property is retained in the cable during its service life. The illustrated cable also differs from a conventional high-voltage cable in that the outer mechanically protecting casing and the metal screen which normally surrounds a conventional cable it may be eliminated.

The invention should not be considered limited to the illustrated embodiment, but may, of course, ~~comprise~~include a number of variations and modifications within the scope of the inventive concept, as it is defined in the subsequent claims. For example, the number

of joints and/or output terminals may be varied where necessary and desired. Further, the winding may, for example, also be installed radially.

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CLAIMS

1. A method for manufacturing a winding of a stator for a rotating electric machine for high voltage, the stator comprising a core (2) provided with slots for receiving the

5 winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end (5) projecting from each end surface (3) of the stator, the coil ends from all the windings of the stator forming a coil overhang (1) at each end (3) of the stator, **characterized** in that  
10 the necessary joints (12) between coils in the winding are placed outside the coil overhang.

2. A method according to claim 1, **characterized** in that the winding comprises an insulated electric conductor (6) and that ends (8, 9, 15) of the insulated electric conductor (6) in the winding are drawn out outside the coil overhang (1) where the respective ends  
15 are joined to ends of other insulated electric conductors (6) in the winding, located there.

3. A method according to claim 1 or 2, **characterized** in that the end (15) of at least one of the insulated electric conductors (6) of the winding is drawn out an optional distance outside the coil overhang, where it forms an output terminal (16) for lower voltage.  
20

4. A method according to any of claims 1-3, **characterized** in that the end (15) of at least one of the insulated electric conductors (6) of the winding is drawn out an optional distance outside the coil overhang, where it is connected to an optional apparatus.

25 5. A method according to any of claims 2-4, **characterized** in that the winding is achieved by threading the insulated electric conductor (6) axially back and forth repeatedly in the slots of the stator core (2).

30 6. A method according to any of the preceding claims, **characterized** in that the insulated electric conductor (6) in the winding is provided with means for enclosing a generated electric field within the winding during at least one winding turn.

7. A method according to any of the preceding claims, **characterized** in that the winding is provided by means of an insulated electric conductor (30) comprising at least

one current-carrying conductor (31), and that said field-enclosing means comprise a first layer (32) with semiconducting properties arranged surrounding the current-carrying conductor, a solid insulating layer (33) arranged surrounding said first layer, and a second layer (34) with semiconducting properties arranged surrounding the insulating layer.

5

8. A method according to claim 7, **characterized** in that the insulated electric conductor (30) is flexible and that said layers adhere to one another.

9. A method according to claim 7 or 8, **characterized** in that the insulated conductor (30) is in the form of a cable, preferably a high-voltage cable.

10. A method according to any of claims 7-9, **characterized** in that said layers (32, 33, 34) are of materials with such elasticity and such a relation between the coefficients of thermal expansion of the materials that the volume changes of the layers, caused by temperature variations during operation, are capable of being absorbed by the elasticity of the materials such that the layers retain their adhesion to one another at the temperature variations which arise during operation.

11. A method according to claim 10, **characterized** in that the materials in said layers (32, 33, 34) have a high elasticity, preferably with an E-modulus less than 500 MPa, preferably less than 200 MPa.

12. A method according to claim 10, **characterized** in that the coefficients of thermal expansion of the materials in said layers are substantially equal.

25

13. A method according to claim 10, **characterized** in that the adhesion between the layers (32, 33, 34) is of at least the same order of magnitude as in the weakest of the materials.

30

14. A method according to any of claims 7-13, **characterized** in that the second semiconducting layer (34) is arranged so as to constitute a substantially equipotential surface surrounding the current-carrying conductor/conductors (31).

15. A method according to claim 14, **characterized** in that the second semi-conducting layer (34) is connected to ground potential.

16. A method according to any of claims 7-10, **characterized** in that each of the  
5 semiconducting layers (32, 34) constitutes essentially an equipotential surface.

17. A method according to any of the preceding claims, **characterized** in that the winding is formed during the final mounting in the core.

10 18. A method according to any of the preceding claims, **characterized** in that a lubricant is supplied when the winding is drawn through the stator slots.

15 19. A method according to any of the preceding claims, **characterized** in that a bracing hose is drawn through the stator slots, after the winding has been drawn, whereby a lubricant is supplied to the slots.

20 20. A method according to any of claims 18-19, **characterized** in that the lubricant is a dry lubricant.

20 21. A method according to any of the preceding claims, **characterized** in that the winding is attached to the stator slots by means of resilient elements.

25 22. A method according to any of claims 7-21, **characterized** in that the insulation system of the winding comprising the first (32) and second (34) semiconducting layers, respectively, and the insulating layer (33) located therebetween, is manufactured by extrusion.

23. A method according to any of claims 7-22, **characterized** in that the insulation of the winding is manufactured of a material with a high coefficient of linear expansion.

30 24. A method according to any of claims 7-23, **characterized** in that the winding has mutually insulated strands in the current-carrying conductor (31).

25. A method according to any of claims 7-24, **characterized** in that the current-carrying conductor (31) of the winding has a continuous, uncontrolled transposition.

26. A method according to any of claims 7-25, **characterized** in that the current-carrying conductor (31) of the winding has a circular cross section.

5 27. A method according to any of claims 7-26, **characterized** in that the current in the current-carrying conductor (31) of the winding is low, preferably less than 1000 A.

10 28. A method according to any of the preceding claims, **characterized** in that the winding has a continuous corona protection device.

29. A method according to claim 28, **characterized** in that the corona protection device is grounded.

15 30. A stator for a rotating electric machine for high voltage, comprising a stator core and a winding, **characterized** in that the winding is manufactured in accordance with the method according to any of claims 1-29.

20 31. A rotating electric machine for high voltage, comprising a stator in accordance with claim 30.

## ABSTRACT

The invention relates to a method for manufacturing a winding of a stator for a rotating electric machine for high voltage, the stator comprising a core (2) provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which extends back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end (5) projecting from each end surface (3) of the stator, the coil ends from all the windings of the stator forming a coil overhang (1) at each end (3) of the stator.

10 The method is characterized in that the necessary joints (12) between coils in the winding are placed outside the coil overhang (1). The invention also relates to a stator with a winding manufactured according to the method and to a rotating electric machine comprising said stator.

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A METHOD FOR MANUFACTURING A STATOR FOR A ROTATING ELECTRIC MACHINE, WHERE THE STATOR WINDING INCLUDES JOINTS, A STATOR AND A ROTATING ELECTRIC MACHINE

The present invention relates to a method for manufacturing the winding of a stator for a rotating electric machine for high voltage in accordance with the preamble to claim 1. The invention also relates to a stator in accordance with the preamble to claim 30, and a rotating electric machine in accordance with the preamble to claim 31.

The rotating electric machines which are referred to in this context comprise synchronous machines, which are principally used as generators for connection to distribution and transmission networks, commonly called power networks. The synchronous machines are also used as motors as well as for phase compensation and voltage control, and, in that case, as mechanically open-circuited machines. This technical field also comprises normal asynchronous machines, double-fed machines, ac machines, asynchronous converter cascades, external pole machines and synchronous flux machines. These machines are intended to be used at high voltages, by which are meant here electric voltages which primarily exceed 10 kV. A typical range of operation for such a rotating machine may be 36 - 800 kV, and preferably 72.5 - 800 kV.

Rotating electric machines have conventionally been designed for voltages within the interval 6 - 30 kV, and 30 kV has normally been considered to be an upper limit. In the generator case, this normally implies that a generator must be connected to the power network via a transformer which steps up the voltage to the level of the network, which lies within the range of about 130 - 400 kV.

Over the years, various attempts have been made to develop special synchronous machines, preferably generators, for higher voltages. Examples of this are described, inter alia, in "Electrical World", October 15, 1932, pages 524-525, the article "Water-and-Oil-cooled Turbogenerator TVM-300" in J. Elektrotechnika, No. 1, 1970, pages 6-8, and patent publications US 4,424,244 and SU 955 369. However, none of these attempts has been successful, nor have they resulted in any commercially available product.

In conventional types of rotating electric machines, the stator body often comprises a welded sheet-steel structure. In large machines, the stator core, also called the laminated core, is normally made of preferably 0.35-0.50 mm thick so-called electric sheets divided into stacks. The stator core is provided with radial slots for receiving the winding in radial layers at different radial distances from the air gap which is provided between the stator and a rotor. The word layer thus means layers of the winding at different radial distances from the centre axis of the stator. That part of the winding which runs back and forth once through the stator between different layers forms one winding turn, and several winding turns are normally collected into a so-called coil. A coil thus comprises several aggregated conductors, insulated from each other, with an arc-shaped coil end outside each end surface of the stator. The coil ends from all the windings of the stator form a coil overhang at each end of the stator.

Normally, all large, conventionally constructed generators are provided with a two-layer winding and equally large coils. The fact that the coils must be equally large is due to the generators for high powers often requiring a parallel connection of the coils. The coils are stiff and prefabricated and the winding is installed by inserting coils in a radial direction into the slots of the stator core. Joining or connection then takes place between each coil in the winding when all the coils have been placed in position in their slots. Because all the coils must have the same size, all the joints must be placed in the coil overhang. The coil overhang will therefore contain a large number of joints. This method has the disadvantage of being time-consuming and results in a number of joints which are sensitive to various kinds of faults and external influence.

The object of the present invention is to solve the above-mentioned problems. This object is achieved by means of the method according to the preamble to claim 1, which has the characteristic features described in the characterizing portion.

Thus, the present invention relates to a method for the manufacture of a winding for a stator of a rotating electric machine for high voltage, wherein the stator comprises a core provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the

stator and the rotor, whereby that part of the winding which runs back and forth once through the stator between various layers forms a coil, with an arc-shaped coil end projecting outside each end surface of the stator, the coil ends from all the windings of the stator forming a coil overhang at each end of the stator, the method being characterized in that the necessary joints in the winding are placed outside the coil overhang.

The method described has the essential advantage that the winding may be jointed or spliced in a very simple manner. Instead of jointing each coil inside the coil overhang, which is narrow and awkward, the winding may thus be jointed outside the coil overhang where there is ample space and easy access. One advantage of the winding of the kind discussed above is that it allows series connection of the coils. In case of a series connection, it is not required that the coils be equally large, and, therefore, a freer location of the necessary joints is possible, which makes the present invention possible.

Another advantage achieved with the method is that it will be possible to provide output terminals for lower voltages in the winding at optional locations, which locations are situated outside the coil end overhang.

Additional advantages and characteristic features will become clear from the dependent claims.

According to a particularly advantageous feature, the method is characterized in that the winding comprises an insulated electric conductor and that ends of insulated electric conductors in the winding are drawn out outside the coil overhang, where the respective ends are joined to ends of other insulated electric conductors in the winding.

According to another advantageous characteristic feature, it is stated that the end of at least one of the insulated electric conductors of the winding is drawn out to an optional extent outside the coil end region, where it forms an output terminal for lower voltage, for example an external power network. The output terminals may be varied as desired as regards location, voltage, number, etc. In principle, such a long conductor may be drawn out that it may be extended to the nearest switchgear, without the need of supporting bars and the like. As an additional advantageous characteristic feature, it is thus stated that the end of at least one of

the insulated electric conductors of the winding is drawn out to an optional extent outside the coil overhang, where it is connected to an optional apparatus. Such an apparatus may be a generator breaker and/or a disconnector or the above-mentioned switchgear and, in that case, it is thus a question of full voltage.

5 Furthermore, the method according to the invention is characterized in that the winding is achieved by threading the insulated electric conductor axially back and forth repeatedly in the slots in the stator core. In this way, many coils, i.e. turns in the winding, may be achieved without interruption and without joints, which is both time-saving and cost-effective. Further, it has the advantage that the  
10 winding is not formed until the final mounting in the stator core and no preforming is therefore required.

According to a particularly advantageous characteristic feature, the insulated electric conductor is provided with means for enclosing a generated electrical field inside the winding for at least one winding turn.

15 According to the invention, the windings are preferably of a type corresponding to cables having solid, extruded insulation, of a type now used for power distribution, such as XLPE-cables or cables with EPR-insulation. Such a cable comprises an inner conductor composed of one or more strand parts, an inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding  
20 this and an outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an important property in this context since the technology for the arrangement according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of an XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.  
25

30 The winding should be constructed to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this context. The ma-

terial properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE-cable, for instance, the insulating layer consists of cross-linked, low-density polyethylene, and the semiconducting layers consist of polyethylene with soot and metal particles mixed in.

5 Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

10 The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having a resistivity within the range of  $10^{-1}$ - $10^6$  ohm·cm, e.g. 1-500 ohm·cm, or 10-200 ohm·cm, naturally also fall within the scope of the invention.

15 The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene ("TPX"), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

20 The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

25 The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

30 Ethylene-vinyl-acetate copolymers/nitrile rubber (EVA/NBR), butyl graft polyethylene, ethylene-butyl-acrylate copolymers (EBA) and ethylene-ethyl-acrylate copolymers (EEA) may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of  $E < 500 \text{ MPa}$ , preferably  $< 200 \text{ MPa}$ . The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks appear, or any other damage, and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as in the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently high to enclose the electrical field within the cable, but sufficiently low not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

By using an insulated conductor as described above as a winding in a rotating electric machine, the important advantage is achieved that the voltage of the machine may be increased to such levels that it may be directly connected to the power network without intermediate transformers. Thus, for example, the very important advantage is achieved that the conventional transformer may be eliminated.

To continue, the winding is further characterized in that it is made with an insulated electric conductor comprising at least one current-carrying conductor, and that the field-enclosing members mentioned comprise a first layer with semiconducting properties arranged to surround the current-carrying conductor, a solid insulating layer arranged to surround the first-mentioned layer, and a second layer with semiconducting properties arranged to surround the insulating layer.

According to a particularly advantageous characteristic feature, the insulated electric conductor is flexible and the three layers adhere to one another, which, among other things, has the advantage of facilitating installation and removal of the winding, respectively.

The high-voltage insulated electric conductor may be designed in a plurality of advantageous ways. As one advantageous feature it is stated that the insulated conductor comprises a cable, preferably a high-voltage cable. Further, the first semiconducting layer is substantially at the same potential as the current-carrying conductor. The second semiconducting layer is preferably arranged so as to constitute a substantially equipotential surface surrounding the current-carrying conductor/conductors and the insulating layer. It is also connected to a predetermined potential, preferably ground potential. According to another characteristic feature, the current-carrying conductor may comprise a number of strands, whereby only a few of the strands are uninsulated from one another.

Finally, it may be mentioned that the insulated conductor preferably has a diameter which is in the interval 20-250 mm and a conductor area which is in the interval 80-300 mm<sup>2</sup>.

The insulated conductor or high-voltage cable which is used in the present invention is, as mentioned, flexible and of the kind described in more detail in PCT applications SE97/00874 (WO 97/45919) and SE97/00875 (WO 97/45847). A further description of the insulated conductor or cable is to be found in PCT-applications SE97/00901 (WO 97/45918), SE97/00902 (WO 97/45930) and SE97/00903 (WO 97/45931).

According to a particularly advantageous feature, the winding is characterized in that it is formed during the final mounting in the core. As already mentioned, this facilitates the manufacture since no preforming is necessary.

The method is also characterized in that a lubricant is supplied when the winding is drawn through the stator slots. Where applicable, a bracing hose for the winding may be drawn through the stator slots, after the winding has been drawn, and the method is then characterized in that a lubricant is supplied to the slots in connection with the bracing hose being drawn. This lubricant is preferably a dry lubricant. An example of a suitable lubricant is boron nitride, preferably of a lamel-

lar structure. Examples of so-called bracing hoses are described in the patent applications SE 9700362-8, SE 9700363-6, PCT/SE97/00897 (WO 97/45935), PCT/SE97/00898 (WO 97/45936), PCT/SE97/00906 (WO 97/45938) and PCT/SE97/00907 (WO 97/45932).

5 Finally, the method is characterized in that the winding is attached in the stator slots by means of resilient elements, for example a bracing hose of some of the kinds stated in the above-mentioned patent applications.

10 Further, the insulation system of the winding comprising the first and second semiconducting layers, respectively, and the insulating layer positioned therebetween, may be manufactured by extrusion. The insulation of the winding is preferably manufactured of a material with a high coefficient of linear expansion.

According to one characteristic feature, the winding has mutually insulated strands in the current-carrying conductor. Further, it is stated that the current-carrying conductor of the winding has a continuous, uncontrolled transposition.

15 This simplifies the manufacture of the winding. The current-carrying conductor also advantageously has a circular cross section, which also has the advantage of simplifying the manufacture in that the conductor may be bent in an arbitrary direction.

20 As a further characteristic feature it is stated that the current in the current-carrying conductor of the winding is low, preferably less than 1000 A. This has the advantage of resulting in lower mechanical forces because of fault currents, compared with conventional machines. It also implies that the bracing of the coil end is simplified.

25 Further, the method is characterized in that the winding has a continuous corona protection device, which is advantageously grounded. The corona protection device comprises the second semi-conducting layer.

30 The present invention also relates to a stator for a rotating electric machine for high voltage, comprising a stator core and a winding, which is characterized in that the winding is manufactured in accordance with the method according to any of the claims relating to the method. The invention also relates to a rotating electric machine for high voltage comprising the stator mentioned.

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In summary, thus, the present invention provides a considerably simplified method for the manufacture of a winding, which shows the way to other improvements and also directly results in technical advantages as well as advantages from the point of view of cost.

To increase the understanding of the invention, it will now be described in detail, with reference to the accompanying drawings, illustrating a non-limiting embodiment, wherein

Figure 1 schematically shows, in perspective, a part view of a stator end with coil ends comprising unjointed conductors,

Figure 2 schematically shows, in perspective view, the stator end in Figure 1, after jointing, and

Figure 3 shows an insulated electric conductor, in cross section, which is suitable for use as a winding.

Figure 1 schematically illustrates an example of a part of a coil overhang 1 of an end surface 3 of a stator core 2 according to the present invention. The figure shows that the winding is arranged in radial layers at different radial distances from the air gap present between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end 5 projecting from each end surface 3 of the stator, the coil ends from all the windings of the stator forming a coil overhang 1 at each end of the stator.

The winding in the figure is achieved by threading a cable or an insulated electric conductor (6) of the kind described above axially back and forth repeatedly in the slots in the stator core 2, whereby a plurality of coils are being formed without joints. However, the length of the cable (6) is not infinite, but sooner or later the first cable comes to an end and a new cable must be used. As a result of this, the coil overhang 1 will exhibit a number of loosely hanging cable ends 8, 9, 15, which, for example, are to be joined with each other. These cable ends are located outside the actual coil overhang 1.

Figure 2 shows the same stator end as in Figure 1 but with the difference that the loose cable ends 8, 9 have here been joined with each other by means of some suitable type of cable joint 12, preferably a prefabricated cable joint. As is

clear, also the joints are outside the coil overhang 1. The joints may possibly be attached mechanically to some type of support, which, however, is not shown in the figure.

In the example shown, the jointing has been performed only after at least  
5 a major part of the winding has been placed in position, but it is, of course, possible to join the cable ends as the winding is being threaded. Usually, however, the entire winding is threaded before jointing takes place.

Figure 2 also shows an example of a winding end 15 which serves as a partial output terminal 16 for voltage or, alternatively, is optionally connected, for  
10 example to a switchgear unit or a generator breaker.

Finally, Figure 3 shows a cross section of a cable which is particularly suited for use as a winding in the stator according to the invention. The cable 30 comprises at least one current-carrying conductor 31 surrounded by a first semiconducting layer 32. Around this first semiconducting layer, there is arranged an insulating layer 33, and around this layer there is arranged, in its turn, a second semiconducting layer 34. The electric conductor 31 may comprise a number of strands 35. The three layers are formed such that they adhere to one another also when the cable is bent. The shown cable is flexible and this property is retained in the cable during its service life. The illustrated cable also differs from a conventional high-voltage cable in that the outer mechanically protecting casing and the metal screen which normally surrounds it may be eliminated.  
15  
20

The invention should not be considered limited to the illustrated embodiment, but may, of course, comprise a number of variations and modifications within the scope of the inventive concept, as it is defined in the subsequent  
25 claims. For example, the number of joints and/or output terminals may be varied where necessary and desired. Further, the winding may, for example, also be installed radially.

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## CLAIMS

1. A method for manufacturing a winding of a stator for a rotating electric machine for high voltage, the stator comprising a core (2) provided with slots for receiving the winding in radial layers at different radial distances from the air gap which is present between the stator and a rotor, whereby that part of the winding which runs back and forth once through the stator between different layers forms a coil, with an arc-shaped coil end (5) projecting from each end surface (3) of the stator, the coil ends from all the windings of the stator forming a coil overhang (1)

5 10 at each end (3) of the stator, **characterized** in that the necessary joints (12) between coils in the winding are placed outside the coil overhang.

2. A method according to claim 1, **characterized** in that the winding comprises an insulated electric conductor (6) and that ends (8, 9, 15) of the insulated electric conductor (6) in the winding are drawn out outside the coil overhang (1) where the respective ends are joined to ends of other insulated electric conductors (6) in the winding, located there.

15 20 3. A method according to claim 1 or 2, **characterized** in that the end (15) of at least one of the insulated electric conductors (6) of the winding is drawn out an optional distance outside the coil overhang, where it forms an output terminal (16) for lower voltage.

25 4. A method according to any of claims 1-3, **characterized** in that the end (15) of at least one of the insulated electric conductors (6) of the winding is drawn out an optional distance outside the coil overhang, where it is connected to an optional apparatus.

30 5. A method according to any of claims 2-4, **characterized** in that the winding is achieved by threading the insulated electric conductor (6) axially back and forth repeatedly in the slots of the stator core (2).

6. A method according to any of the preceding claims, **characterized** in that the insulated electric conductor (6) in the winding is provided with means for enclosing a generated electric field within the winding during at least one winding turn.

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7. A method according to any of the preceding claims, **characterized** in that the winding is provided by means of an insulated electric conductor (30) comprising at least one current-carrying conductor (31), and that said field-enclosing means comprise a first layer (32) with semiconducting properties arranged surrounding the current-carrying conductor, a solid insulating layer (33) arranged surrounding said first layer, and a second layer (34) with semiconducting properties arranged surrounding the insulating layer.

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8. A method according to claim 7, **characterized** in that the insulated electric conductor (30) is flexible and that said layers adhere to one another.

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9. A method according to claim 7 or 8, **characterized** in that the insulated conductor (30) is in the form of a cable, preferably a high-voltage cable.

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10. A method according to any of claims 7-9, **characterized** in that said layers (32, 33, 34) are of materials with such elasticity and such a relation between the coefficients of thermal expansion of the materials that the volume changes of the layers, caused by temperature variations during operation, are capable of being absorbed by the elasticity of the materials such that the layers retain their adhesion to one another at the temperature variations which arise during operation.

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11. A method according to claim 10, **characterized** in that the materials in said layers (32, 33, 34) have a high elasticity, preferably with an E-modulus less than 500 MPa, preferably less than 200 MPa.

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12. A method according to claim 10, **characterized** in that the coefficients of thermal expansion of the materials in said layers are substantially equal.

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13. A method according to claim 10, **characterized** in that the adhesion between the layers (32, 33, 34) is of at least the same order of magnitude as in the weakest of the materials.

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14. A method according to any of claims 7-13, **characterized** in that the second semi-conducting layer (34) is arranged so as to constitute a substantially equipotential surface surrounding the current-carrying conductor/conductors (31).

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15. A method according to claim 14, **characterized** in that the second semi-conducting layer (34) is connected to ground potential.

16. A method according to any of claims 7-10, **characterized** in that each of the semiconducting layers (32, 34) constitutes essentially an equipotential surface.

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17. A method according to any of the preceding claims, **characterized** in that the winding is formed during the final mounting in the core.

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18. A method according to any of the preceding claims, **characterized** in that a lubricant is supplied when the winding is drawn through the stator slots.

19. A method according to any of the preceding claims, **characterized** in that a bracing hose is drawn through the stator slots, after the winding has been drawn, whereby a lubricant is supplied to the slots.

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20. A method according to any of claims 18-19, **characterized** in that the lubricant is a dry lubricant.

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21. A method according to any of the preceding claims, **characterized** in that the winding is attached to the stator slots by means of resilient elements.

22. A method according to any of claims 7-21, **characterized** in that the insulation system of the winding comprising the first (32) and second (34) semiconducting layers, respectively, and the insulating layer (33) located therebetween, is manufactured by extrusion.

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23. A method according to any of claims 7-22, **characterized** in that the insulation of the winding is manufactured of a material with a high coefficient of linear expansion.

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24. A method according to any of claims 7-23, **characterized** in that the winding has mutually insulated strands in the current-carrying conductor (31).

25. A method according to any of claims 7-24, **characterized** in that the current-carrying conductor (31) of the winding has a continuous, uncontrolled transposition.

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26. A method according to any of claims 7-25, **characterized** in that the current-carrying conductor (31) of the winding has a circular cross section.

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27. A method according to any of claims 7-26, **characterized** in that the current in the current-carrying conductor (31) of the winding is low, preferably less than 1000 A.

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28. A method according to any of the preceding claims, **characterized** in that the winding has a continuous corona protection device.

29. A method according to claim 28, **characterized** in that the corona protection device is grounded.

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30. A stator for a rotating electric machine for high voltage, comprising a stator core and a winding, **characterized** in that the winding is manufactured in accordance with the method according to any of claims 1-29.

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31. A rotating electric machine for high voltage, comprising a stator in accordance with claim 30.

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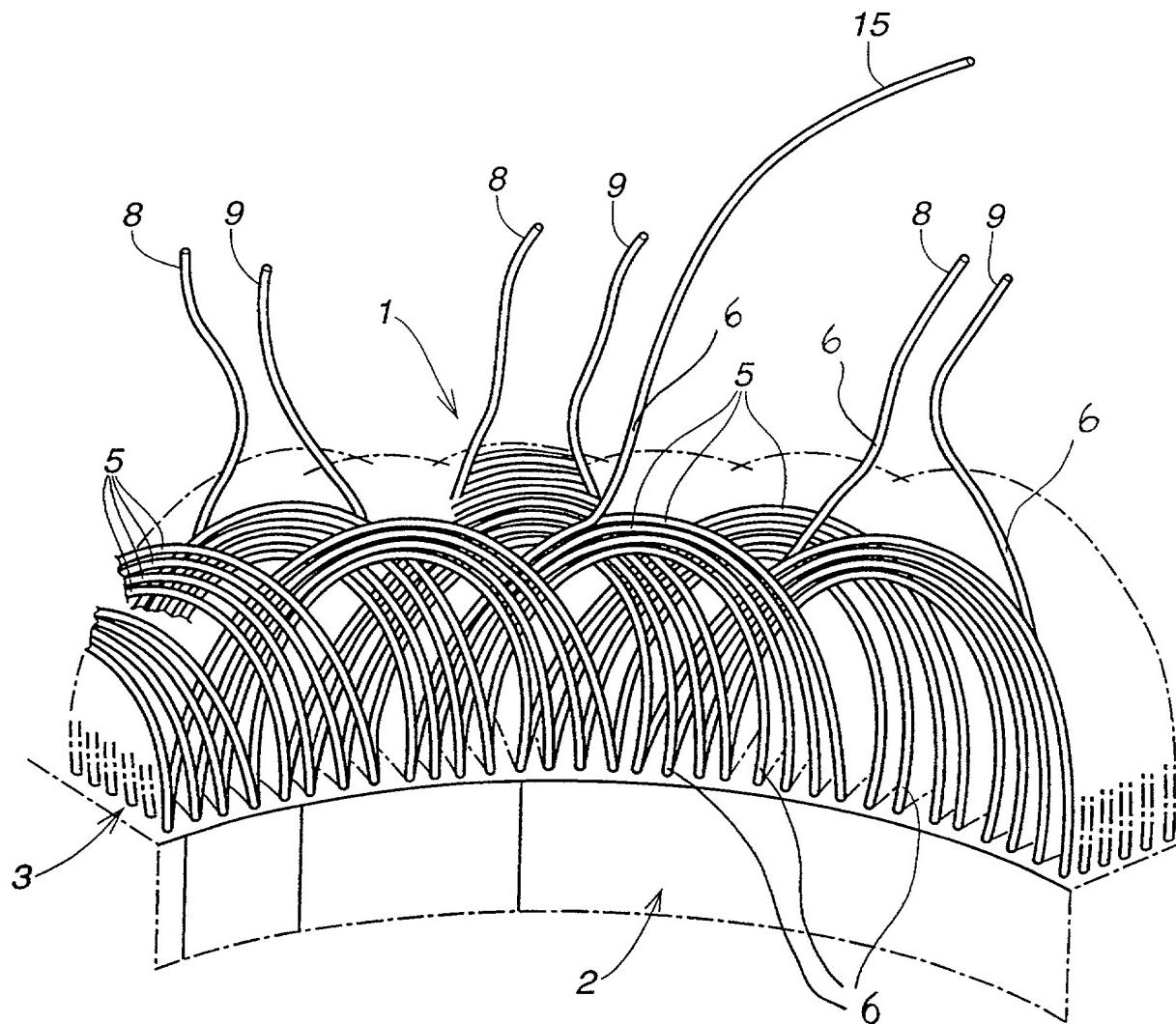


Fig. 1

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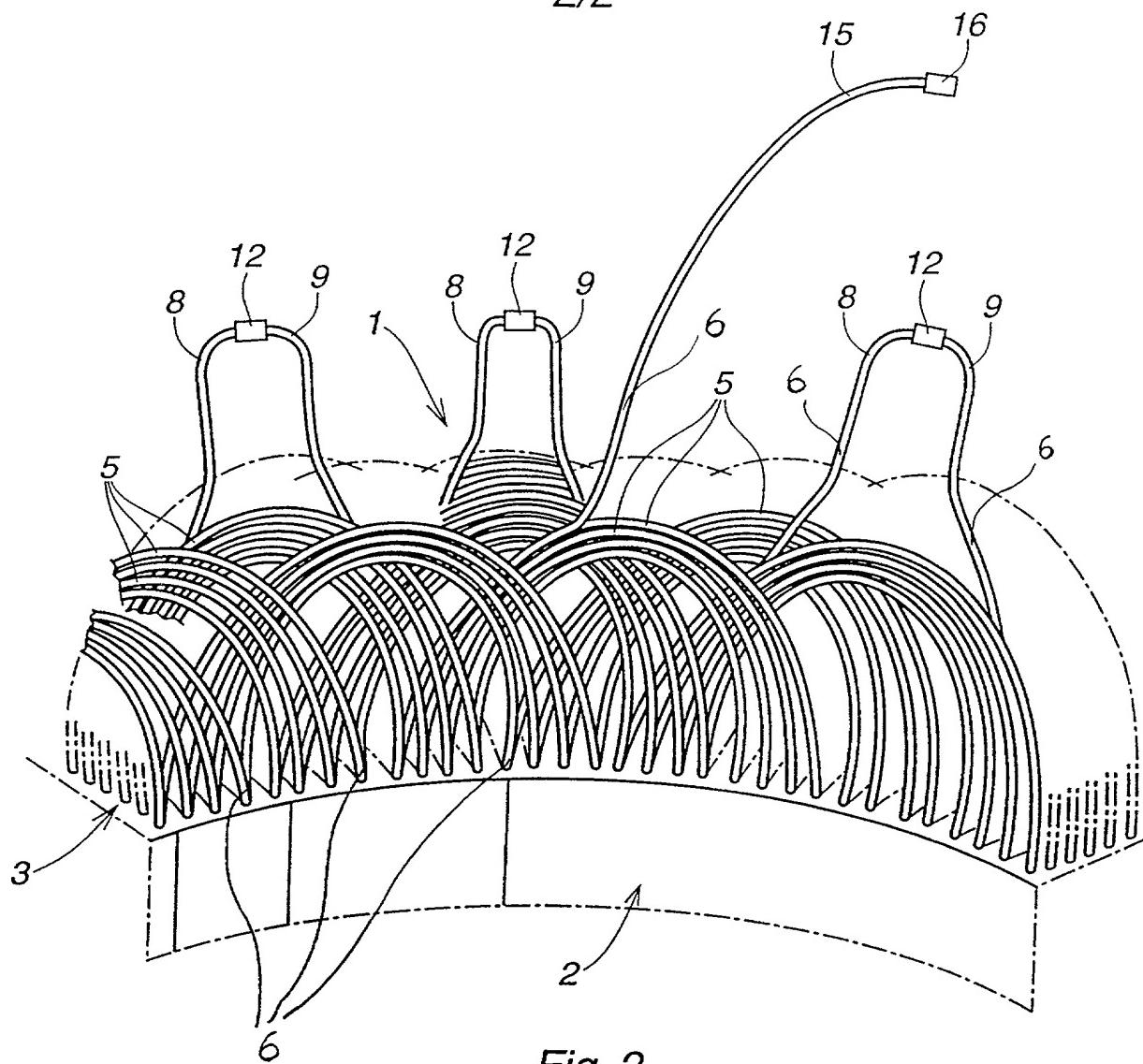


Fig. 2

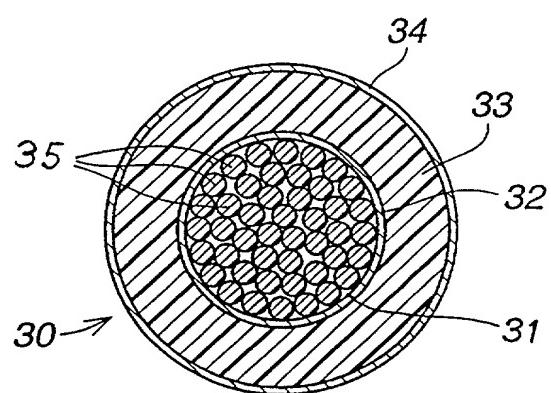


Fig. 3

# Declaration, Power Of Attorney and Petition

Page 1 of 3

WE (I) the undersigned inventor(s), hereby declare(s) that:

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

A METHOD FOR MANUFACTURING A STATOR FOR A ROTATING ELECTRIC MACHINE, WHERE

THE STATOR WINDING INCLUDES JOINTS, A STATOR AND A ROTATING ELECTRIC MACHINE

the specification of which

- is attached hereto.
- was filed on 22 MAY 2000 as  
Application Serial No. \_\_\_\_\_  
and amended on \_\_\_\_\_.
- was filed as PCT international application  
Number PCT/SE98/02166,  
on 27 NOVEMBER 1998,  
and was amended under PCT Article 19  
on \_\_\_\_\_ (if applicable).

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application(s)

Application No.	Country	Day/Month/Year	Priority Claimed
<u>9704461-4</u>	<u>SWEDEN</u>	<u>28 NOVEMBER 1997</u>	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
_____	_____	_____	<input type="checkbox"/> Yes <input type="checkbox"/> No
_____	_____	_____	<input type="checkbox"/> Yes <input type="checkbox"/> No
_____	_____	_____	<input type="checkbox"/> Yes <input type="checkbox"/> No

We (I) hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

Application Serial No.	Filing Date	Status (pending, patented, abandoned)
PCT/SE98/02166	27 NOVEMBER 1998	

- And we (I) hereby appoint: Norman F. Oblon, Reg. No. 24,618; Marvin J. Spivak, Reg. No. 24,913; C. Irvin McClelland, Reg. No. 21,124; Gregory J. Maier, Reg. No. 25,599; Arthur I. Neustadt, Reg. No. 24,854; Richard D. Kelly, Reg. No. 27,757; James D. Hamilton, Reg. No. 28,421; Eckhard H. Kuesters, Reg. No. 28,870; Robert T. Pous, Reg. No. 29,099; Charles L. Gholz, Reg. No. 26,395; William E. Beaumont, Reg. No. 30,996; Jean-Paul Lavallee, Reg. No. 31,451; Stephen G. Baxter, Reg. No. 32,884; Richard L. Treanor, Reg. No. 36,379; Steven P. Weihrouch, Reg. No. 32,829; John T. Goolkasian, Reg. No. 26,142; Richard L. Chinn, Reg. No. 34,305; Steven E. Lipman, Reg. No. 30,011; Carl E. Schlier, Reg. No. 34,426; James J. Kulbaski, Reg. No. 34,648; Richard A. Neifeld, Reg. No. 35,299; J. Derek Mason, Reg. No. 35,270; Surinder Sachar, Reg. No. 34,423; Christina M. Gadiano, Reg. No. 37,628; Jeffrey B. McIntyre, Reg. No. 36,867; William T. Enos, Reg. No. 33,128; Michael E. McCabe, Jr., Reg. No. 37,182; Bradley D. Lytle, Reg. No. 40,073; and Michael R. Casey, Reg. No. 40,294; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C., whose Post Office Address is: Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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